SECTOR RADIO MEASUREMENTS OF METEOR TRAIL DRIFTS BY LOW FREQUENCY RADAR TRANSMISSIONS

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ABSTRACT. The use of the "sector" method to record meteor trail drifts by radars using a sampling rate of F_r = 100-200 pps is described.

The results of observations of meteor trail drifts by radio methods are very much dependent on the number of recorded meteor reflections from which the Doppler frequency shift can be measured [1]. /56

In 1953, L. A. Manning [2], in a variant of continuous radiation, used the vector method of indicating meteor echoes, so that short reflections (τ_e = 0.02 - 0.05 sec) could be used for Doppler measurements.

Later, in 1957, V. V. Sidorov [3] performed vector recording of the phase characteristics of reflected signals in a pulse variant.

This article describes the use of the "sector" method of recording meteor trail drifts at radars with a sampling rate of F_r = 100-200 pps.

The "Sector" Recording Method

The results of meteor trail drift observations in the IQSY period after 1964 at the SOM-1 meteor radar (Frunze) were processed and showed that a significant part (25-30%) of all recorded meteor echoes are brief specular reflections. The duration of these reflections is less than one Doppler period ($\tau_e < T_g$), so it is impossible to determine wind characteristics of such echoes by the phase-time method.

A direct count of the experimental material, obtained by the phase-time method, showed that the relative number of useful reflections is equal to 0.60. This result agrees well with that obtained in reference [3].

The expression for the ratio between the number of useful reflections and the total number of reflections has the form

$$\frac{N_u}{N_t} = \int_0^\infty P(t) \cdot F(t) dt, \qquad (1)$$ /57

where

$P(t)dt$ is the probability that the duration of the meteor reflection, τ_e, is in the limits from t to t + dt;

$F(t)$ is the probability that $T_g \leq t$.

Integrating Eq. (1) yields $N_u/N_t = 0.56$.

Therefore, only 56-60% of all the meteor reflections recorded by the phase-time method yields to processing.

The relative number of useful reflections does not depend on recording time t_r for meteor reflections with $\tau_e > T_g$. Line a in Figure 1 shows the relative number of useful reflections in terms of recording time.

The following formula was used to find the relative number of useful reflections in the case of the sector recording method

$$\frac{N_u}{N_t} = [1 - F(\tau_e \leq t_r)]\,[F(T_g \leq t_c) - F(T_g \leq t_r)], \qquad (2)$$

where

$$t_c = \frac{2\pi t_r}{m\delta\bar{\theta}};$$

$\delta\theta$ is the mean error in determining the position of the drift velocity vector; /58

m is a parameter chosen because of the requirement for measurement accuracy, but less than 2π;

$F(T_g)$ is the integral distribution of the Doppler periods;

$F(\tau_e)$ is the integral distribution of meteor reflection durations.

As is evident from Eq. (2), the relative number of useful reflections depends on recording time, t_r. Hence, the usefulness of each meteor will be determined by the probability that the time of its existence will be longer than the recording time ($\tau_e > t_r$), but not longer than the Doppler period ($\tau_e > T_g$), as is the case for phase-time recording.

Taking these experimental data as the original data, and using Eq. (2), we obtain a graph for relative number of useful reflections in terms of

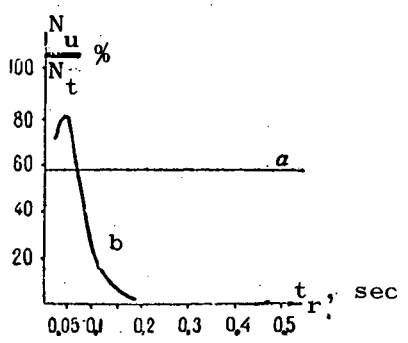

Figure 1. Number of useful reflections in terms of recording time.

recording time (curve b in Figure 1). The "sector" method provides a gain of 25% in the number of measured Doppler echoes when recording time is t_r = 0.04 sec.

Thus, changing from the phase-time to the "sector" recording method provides an increase in the number of useful reflections from 56% to 80%.

It is known [4] that $N \sim P^{1/2}$, so such an increase in the number of measured echoes is extremely significant for comparatively low power (of the order of 40-60 kW) wind radars.

Selection of Number of Pulses for Determining the Phase Vector Angle of Rotation

The minimum number of "illuminating" pulses, sufficient for an accurate determination of the phase vector angle of rotation, $\Theta(t)$, can be determined from the well-known expression

$$t_r \geq \frac{n_{min}}{F_r}, \qquad (3)$$

where

n_{min} is the minimum number of "illuminating" pulses;

F_r is the sampling rate for the radar.

The recording time selection should satisfy the condition of providing the necessary overlap of possible Doppler period values for the largest number of recorded useful echoes. /59

The experimental data obtained by the SOM-1 meteor radar (Frunze) were used to construct a Doppler period distribution curve. This curve (Figure 2) shows that the most probable Doppler period values are in the limits of $0.03 \leq T_g \leq 0.26$ sec. Limiting the angle of rotation for the reflected vector to $\pi/3 \leq \Theta(t) \leq 7\pi/4$, we can establish that optimum recording time is t_r = 0.045 sec from the formula

$$\Theta(t) = \frac{2\pi t_r}{T_g}. \qquad (4)$$

Curve b (Figure 1) makes it apparent that the number of useful reflections is very critical in recording time selection. The maximum number of useful reflections is obtained when the recording time is t_r = 0.04 - 0.05 sec.

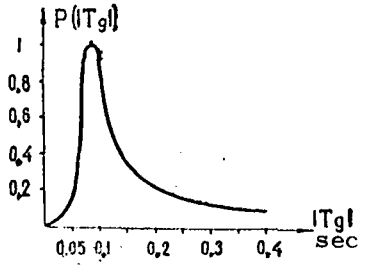

Figure 2. Doppler period distribution.

The use of a radar sampling rate of from 50 to 200 pps [5, 6] is necessary, and sufficient, for measuring wind in the upper layers of the atmosphere from meteor trail drift observations.

The minimum number of "illuminating" pulses for specified recording times and sampling rates can be found by using Eq. (3).

Table 1 leads to the conclusion that four "illuminating" pulses are quite sufficient for establishing the angle of rotation, $\Theta(t)$, characterizing the radial component of the meteor trail drift rate when F_r = 100 pps. /60

TABLE 1

F, pps	50	100	150	200
n, min	2	4	6	8

Determination of the Direction of Meteor Trail Drift in Space

Determination of the direction of meteor trail drift in space is highly important in processing Doppler velocities.

The evaluation of the sign for rotation of the reflected vector as "toward" or "away" was made in earlier work with equipment with sector recording by the increase in the brightness of the initial intensification, or by a break in the initial section of the series of intensifier pulses.

The major deficiency in the first method is the effects of film development. The second method is suitable only for radars with high

sampling rates.

We had four intensifier pulses, so we introduced an additional main pulse, an AMP, to provide reliable determination of the direction of meteor trail drift. The sign of reflected vector rotation can be evaluated from the position of the additional main pulse, whether it is to the right, or left, of the reference pulse.

Additional Main Pulse Block Diagram

The additional main pulse unit determines the direction of the meteor trail drift in space. The functional diagram is shown in Figure 3.

The main pulse is fed from the transmitter to stretcher 1. The width of the pulse from the stretcher should be such that the AMP is not contained in the meteor recording working zone with respect to the "time window" range. The radar "window" usually is established during observations such that the signal receiver is unblocked from the moment in time corresponding to the arrival of reflections from a distance of 100 km, and is blocked for distances greater than 500 km. In this connection, the stretcher /61 shapes a 7-8 msec pulse.

The pulse flows through differentiating circuit 2, and gating stage 3 is triggered by the trailing edge, generating a 20-30 msec pulse that triggers the transmitter keyer. This pulse will be called the TKT pulse in what follows. The TKT pulse flows from gating stage 3 to passage enabling stage 6.

The enabling stage operates in the following manner. A radio echo reflected from a meteor trail is duration and amplitude selected and flows from amplitude discriminator 11 to shaping stage 10. The shaping stage generates a 15-20 μsec signal which is supplied to the stage that shapes the pulse that enables TKT passage. The width of the TKT passage enabling pulse is 7-8 msec.

No command signal is generated when no radio echo is reflected from a meteor trail, the plate of gating stage 3 is shunted by the diode, and the amplitude of the TKT pulse becomes too small to trigger the threshold circuit 5. Presence of a TKT passage enabling pulse prevents the plate

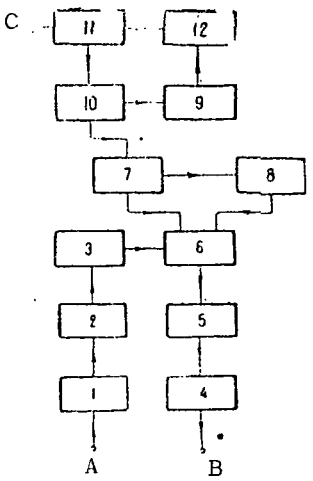

Figure 3. Functional diagram of the unit for shaping the additional main pulse.

load on gating stage 3 from being shunted by the diode. After passage is enabled, the TKT pulse flows to threshold circuit 5, and then to mixing stage 4 in the MO unit (pulse master oscillator). The TKT pulse flows from the MO unit to the transmitter modulator, shaping the AMP.

The trailing edge of the TKT passage enabling pulse, 7, generates a TKT inhibit pulse, 8, to prevent passage of subsequent TKT pulses, and thus prevent the shaping of the second, third, and other AMP. The TKT inhibit pulse is 25-30 msec in width, the time necessary to disconnect the passage enabling stage, 6, for the duration of three main pulses from a transmitter with a radar sampling rate of F_r = 100 pps. /62

The command signal triggers intensification resolution stage 9 shaping a 38 msec intensification resolution pulse. The pulse is fed from stage 9 into intensification discriminator 12 and gives the command to intensify four pulses reflected from the meteor trail.

The command signal is fed to a relay that disconnects the receiver from the indicator after 0.05 sec for from 10 sec to 1 min. The relay disconnects the indicator to prevent intensification of a $\tau_e > 0.05$ sec radio echo, and superposition of the vector diagrams.

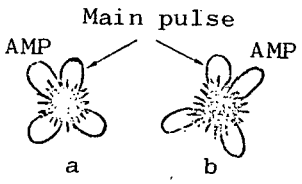

Figure 4. Sample sector recording of meteor echoes.

Figure 4 is a sample sector recording of meteor echoes using an artificial meteor. In conclusion, it should be pointed out that a similar sector recording method is essential for relatively low power radars (P = 40-60 kW) with comparatively low pulse frequency (F_r = 50-200 pps) and used for measuring meteor trail drifts in space.

REFERENCES

1. Greenhow, J. S., Neufeld, E. L., Phil. Mag., Vol. 1, No. 12, Dec. 1956, pp. 1157-1171.

2. Manning, L. A., Villard, O. G., Peterson, A. M., J. Geophys. Res., Vol. 57, Sept. 1952, pp. 387-403.

3. Sidorov, V. V., Radiometeornyye metody i apparatura dlya nablyudeniya dvizheniy v verkhney atmosfere [Radar Meteor Methods and Equipment for Observation of Movements in the Upper Atmosphere], Thesis, Kazan', 1963.

4. Fialko, Ye. I., Nekotoryye problemy radiolokatsii meteorov [Some Problems of Radar Observations of Meteors], TGU Press, Tomsk, 1961.

5. Robertson, D. S., Liddy, D. T., Elford, W. G., J. Atmos. and Terr. Phys., Vol. 4, No. 4-5, 1953, pp. 255-270.

6. Greenhow, J. S., Philos. Mag., Vol. 45, No. 364, 1954, pp. 471-490.